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VIDEO IMAGING OF CHARGE IIB AURORAL STREAKS

University of Alaska

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The 120 km region conjugate to the CHARGE IIB payload (Poker Flat, Alaska, March 29, 1992) was observed with a pair of low-light level TV systems. A single auroral streak observed as the payload passed through 113 km on the downleg (+466s) confirmed that the electron beam escaped the vicinity of the payload. The lack of any other detected streaks would be consistent with a beam current (peak) of less than 1.6 A. The location of the payload relative to the star background at re-entry was consistent (within 2km) with the radar trajectory. The intensified CCD camera was found to provide a high quality picture with slightly lower sensitivity than that of the older image orthicon camera.

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ABSTRACT

The 120 km region conjugate to the CHARGE IIB payload (Poker Flat, Alaska, March 29, 1992) was observed with a pair of low-light-level TV systems. A single auroral streak observed as the payload passed through 113 km on the downleg (+466s) confirmed that the electron beam escaped the vicinity of the payload. The lack of any other detected streaks would be consistent with a beam current (peak) of less than 1.6 A. The location of the payload relative to the star background at re-entry was consistent (within 2 km) with the radar trajectory. The intensified CCD camera was found to provide a high quality picture with slightly lower sensitivity than that of the older image orthicon camera.

INTRODUCTION

The CHARGE IIB experiment, launched from Poker Flat at 7:27:00 UT on March 29, 1992, was centered around an electron accelerator that launched nominally 3 kV electrons along the magnetic field. Through the greater portion of the flight, the electrons were ejected generally downward where they would be expected to deposit the bulk of their energy in the atmosphere at an altitude of approximately 120 km (Rees, 1963; Banks, et al, 1974). The Geophysical Institute of the University of Alaska Fairbanks operated a pair of low-light-level televisions systems on a steerable mount at Poker Flat to view the weak auroral streaks produced by the electron beam. One camera was a newly designed intensified CCD system. The other, included because of its proven capability and to provide continuity with previous electron accelerator experiments, was a low-light-level version image orthicon camera.

EXPERIMENTAL RESULTS

An initial review of the videotapes confirmed that both cameras operated properly through the flight. The image orthicon had slightly greater sensitivity as judged by the limiting star magnitudes in the two videotapes. Since the image orthicon also had a somewhat larger field of view, the analysis effort was concentrated on this camera. No artificial auroral streaks were detected in the unprocessed data. After performing an 8-frame running average, we were able to see a streak emanating from the rocket upon re-entry, in the last few seconds of the accelerator's operation.

Subsequent analysis showed that the radar angles provided in real time for the 110s point were in error. The result was that the cameras were aimed based on a trajectory that was longer and lower than the

actual trajectory. For much of the flight, the 120 km intercepts of the field lines through the payload were out of the field of view of the camera. Nonetheless, seven time periods were identified that met the following conditions

1) The accelerator was aimed downward.
2) The accelerator was functioning nominally.
3) The 120 km intercept was within the field of view.
4) The camera was not moving.

The selected times were: 178s, 203s, 273s, 347s, 355s, 430s, and 456s. For each of these times, the pointing angle and the angular field of view of the TV camera were calibrated by comparing the observed star field to the Smithsonian Astrophysical Observatory catalog. Based on the trajectory of the payload (Myers, personal communication) and a model field, the field line through the payload down to 120 km altitude was projected on the TV image. Using these projections as guides to the expected location and orientation of the auroral streaks, an intensive effort was made to locate additional streaks in both the original video data and in the time-averaged video. None were found. Hence I conclude that the streaks were below the sensitivity threshold of the camera.

Hallinan et al (1978), based on TV data from the ECHO IV flight, showed that for electron beams between 26 kV and 38 kV energy, the threshold power for detection with the image orthicon TV camera was approximately 1 kW. This threshold should not depend strongly on the electron energy. Lower energy electrons produce somewhat longer streaks and therefore a lower peak brightness for an equivalent power. However, the longer streaks are also easier to detect by eye on the TV monitor. So these effects tend to cancel.

However, during the CHARGE IIB flight, there was a weak diffuse aurora (Figure 1) that resulted in some degradation from the nearly ideal viewing conditions that prevailed during the Echo IV flight. Specifically, the limiting stellar magnitude of the stars detected in single-frame TV images at the beginning of the ECHO IV flight was 9.0 whereas the corresponding value for CHARGE IIB was 8.0. Based on the definition of stellar magnitudes, this represents a relative reduction in sensitivity of 2.5. Hence it is concluded that, for a streak to have been detected in the TV, it would have had to represent an average power of greater than 2.5 kW. Assuming a 3 kV beam, this implies an average current of 0.83 A. Since the beams all had a high frequency modulation, the peak current required for detection would have been 1.6 A.

There were two electron guns on the payload and the nominal current was 1 A for each gun. However, according to Myers and Ernstmeyer (1992), one of the guns underperformed. Hence the total peak current was less than 2.0 A. It would appear that the streak intensities should have been just at or just above the threshold for detection. Yet, prior to re-entry, none were detected. There are several possible interpretations for the failure to detect the streaks.

1) By far the best opportunity for detection was near 07:29:58 (T + 178 s). At this time the camera was aimed such that the entire streak would have been within the picture, and the high elevation angle provided the best seeing conditions of the flight. If the guns were producing a total of 1.6 A peak current at this time,

the streak should have been visible. However, if the guns were not functioning fully at this time, but only subsequently achieved 1.6 A, the streaks would not have been detected.

2) The sensitivity estimates for the TV camera are based on the experience with ECHO IV, which used approximately 30 kV beams. It is possible that the ability to detect beams from lower energy electrons is poorer than the prediction based on the 20 kV beams.

3) Charging of the vehicle, perhaps up to a few hundred volts, would have relatively little effect on 30 kV beams, but would be proportionately large compared to 3 kV. Since the beams are predicted to be at best only marginally detectable, any vehicle charging would reduce the power output below the visibility threshold. However, we note that the gas releases should have controlled charging.

At 7:34:46 (T + 466 s), the payload itself was at an altitude of 116 km and was within the TV picture. By this time, the elevation angle of the payload from Poker was only 17 degrees, and the increased path-length through the atmosphere and through the diffuse aurora had caused some loss in sensitivity compared to the beginning of the flight. Nonetheless, in the time-averaged video, it is possible to see a short streak emanating from the payload. It appears to extend about three kilometers from the payload, a reasonable range for electrons of a few kV at this altitude. (O'Neil et al, 1978 predicted a 2.3 km range for 3 Kev electrons at 116 km.)

In passing, we note that the location of the payload at 07:34:51 agrees with that given in the official trajectory (67.963, -146.618, 107.21 km) within about 2 km. This level of accuracy is more than adequate for the foregoing analysis.

CONCLUSION

Based on the observed streak at the end of the flight, it is concluded that the electron accelerator was operating properly and that the beam was escaping the vicinity of the payload. The lack of other observed streaks implies that the beam current (peak) was probably less than about 1.6 A, at least near the beginning of the flight (178 s). The somewhat compromised viewing conditions precluded setting the limit any lower. It is also concluded that the image orthicon camera was superior to the intensified CCD camera, but that the difference in sensitivity was slight. The lack of instrumental shading in the CCD camera gave it a more generally pleasing appearance. Finally, the observation of the payload at 471 s allows us to verify the general accuracy of the official trajectory.

FIGURES

Figure 1. A meridian scan (North to South) of the 5577 A intensity observed from Poker Flat at the time of gun turn on. The 120 km intercept of the field line through the payload at this time was at a 43 degree elevation angle.

Figure 2. At 07:34:46, as the payload re-entered the atmosphere, a weak streak was seen extending downward from the payload, which appeared just below the bright star. During video playback, the streak is easily detectable owing to its pulsing and the vehicle motion. Although more difficult to see in still photographs, it can be recognized in this one-second exposure. The field of view is 7.5 degrees (elevation) by 9.4 degrees (azimuth).

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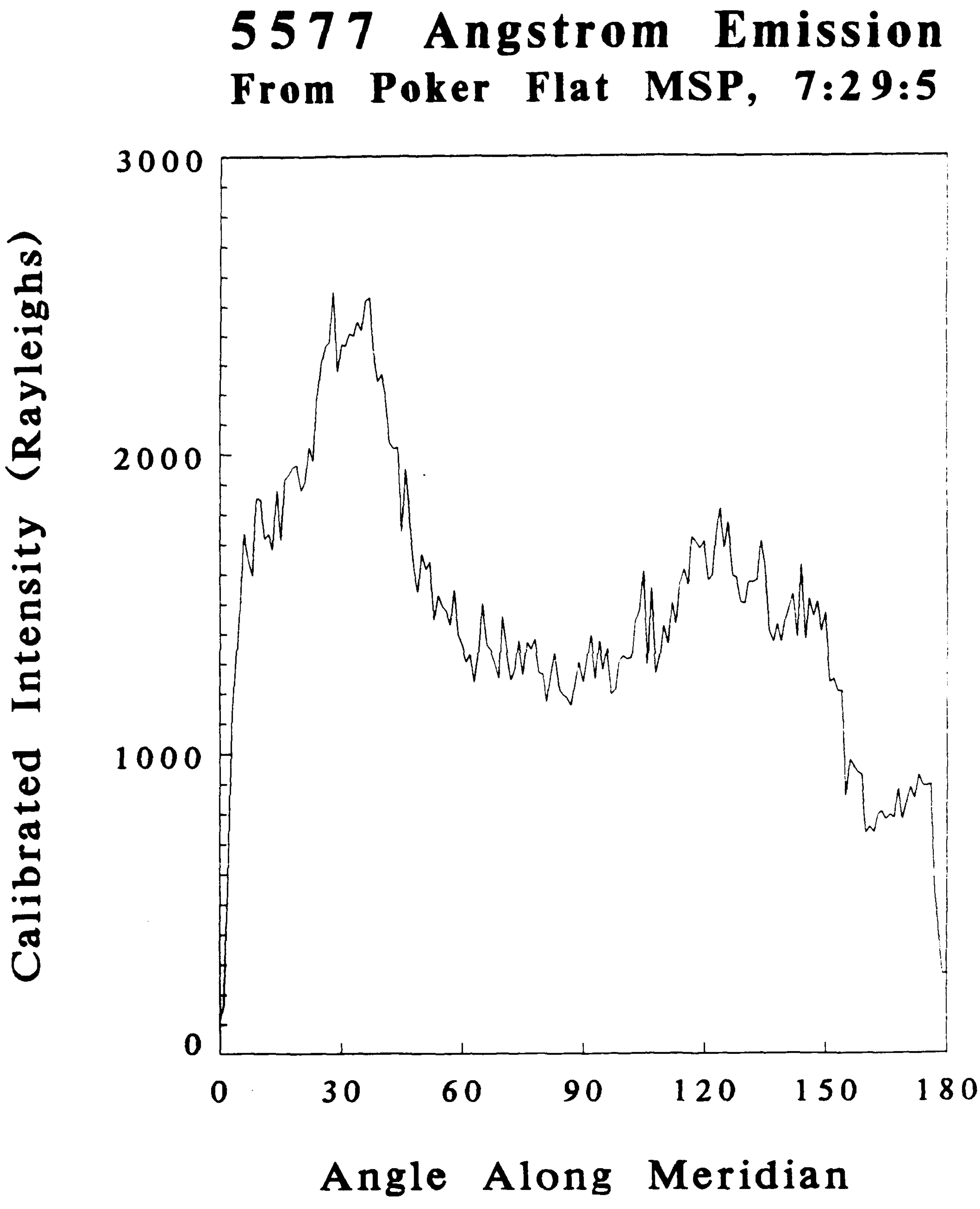

5577 Angstrom Emission
From Poker Flat MSP, 7:29:5
Calibrated Intensity (Rayleighs)
3000
2000
1000
0
0
30
60
90
120
150
180
Angle Along Meridian

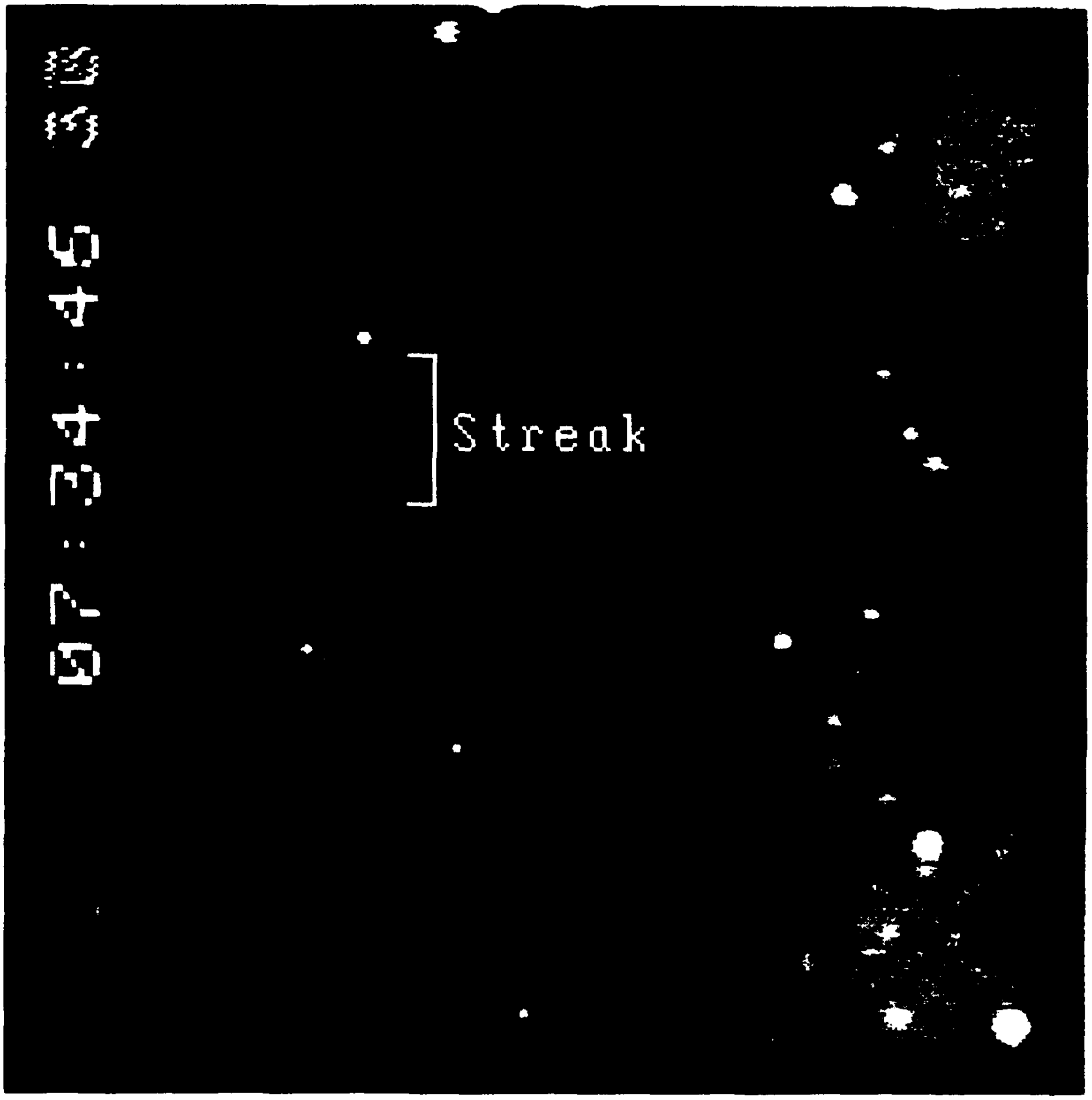

Figure 2

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